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Groh

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(54) **MICROPHONE ARRANGEMENT WITH IMPROVED DIRECTIONAL CHARACTERISTIC**

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H04R 1/40 (2006.01)
H04R 3/00 (2006.01)

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CPC ***H04R 1/326*** (2013.01); ***H04R 1/406*** (2013.01); ***H04R 3/005*** (2013.01)

(58) **Field of Classification Search**
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See application file for complete search history.

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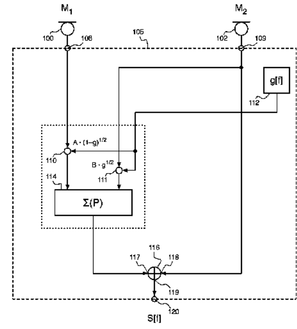
(74) *Attorney, Agent, or Firm* — Workman Nydegger

(57) **ABSTRACT**

A microphone arrangement with improved directional characteristics is provided with at least two microphones (**100**, **102**) and a signal processing arrangement (**105**). The signal processing arrangement is provided with a first (**108**) and a second input (**109**) for receiving the microphone signals of the at least two microphones. The inputs (**108**,**109**) are coupled to signal inputs of a first (**110**) and a second (**111**) multiplication circuit. The multiplication circuits are provided with control inputs for receiving respective first and second control signals, and with signal outputs. A control signal generator (**112**) is provided for generating the first and second control signals for the multiplication circuits (**110**, **111**). An arrangement (**114**) for a power corrected summation is provided, having a first and a second input coupled to the outputs of the first and second multiplication circuit, respectively, and having an output. A signal combination circuit (**116**) is provided with a first input (**117**) coupled to the output of the power corrected summation arrangement (**114**), a second input (**118**) coupled to one of the at least two microphones (**102**), and an output (**119**) coupled to the output (**120**) of the combination circuit (**116**). The first multiplication circuit (**110**) is adapted to multiply the signal applied to its input by a multiplication factor $A^*(1-g)^{1/2}$, under the influence of the first control signal. The second multiplication circuit (**111**) is adapted to multiply the signal applied to its input by a multiplication factor $B^*g^{1/2}$ under the influence of the second control signal. The multiplication factor g is frequency dependent (g[f]), and A and B are constant values, whose absolute values are preferably equal to 1. Further, A=B or A=−B applies. Preferably, the multiplication factor g[f], below a first frequency value, has a smaller value for increasing frequencies. Below a second frequency value that is smaller than the first frequency value, g[f] is a constant value (V), preferably equal to zero. (FIG. **2***a*) Thereby, a microphone arrangement can be obtained which exhibits a desired directional characteristics over an increased frequency range.

18 Claims, 16 Drawing Sheets



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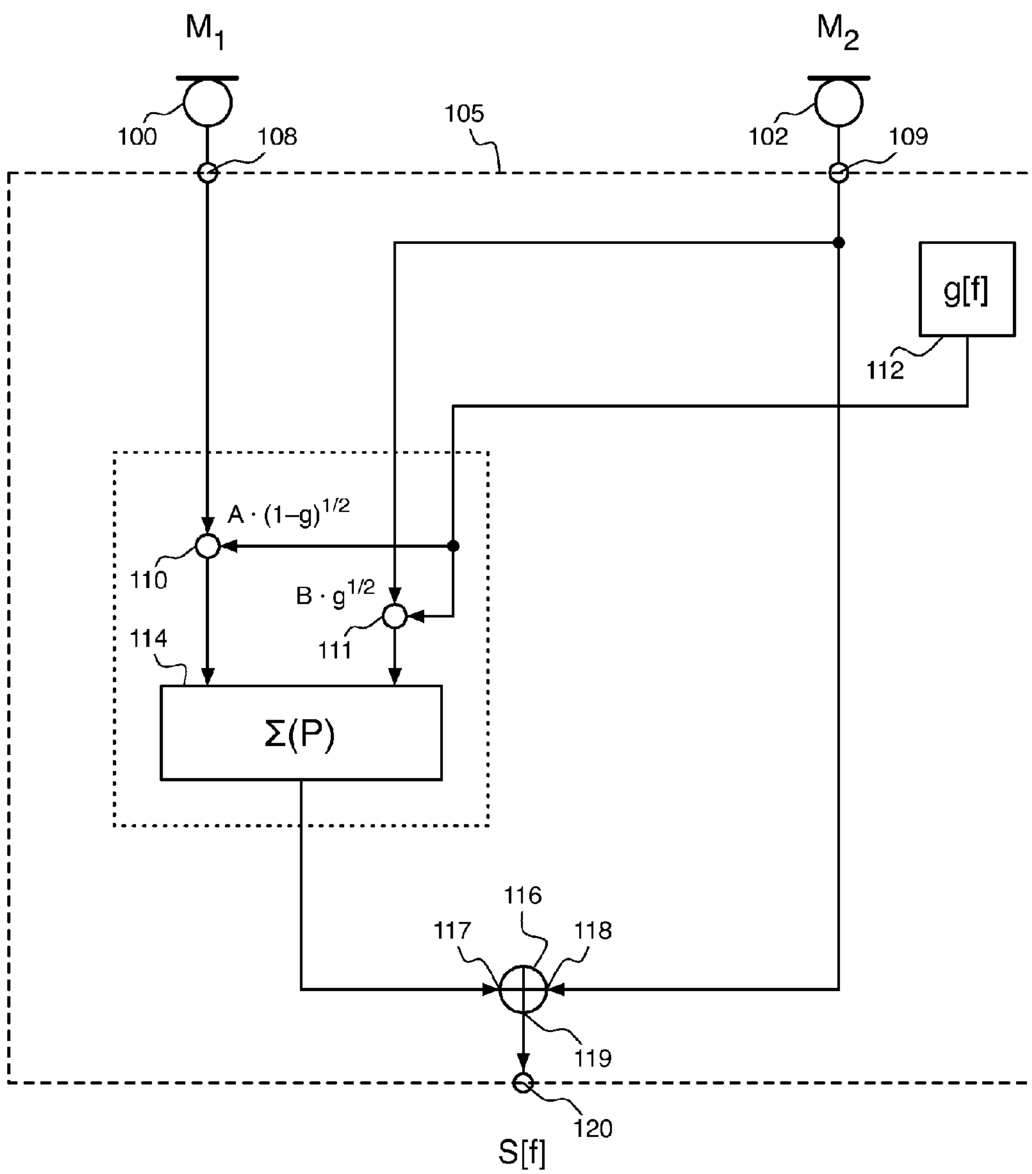

M1
M2
100
108
105
102
109
g[f]
112
A · (1–g)^1/2
110
B · g^1/2
111
114
Σ(P)
116
117
118
119
120
S[f]

Fig. 1

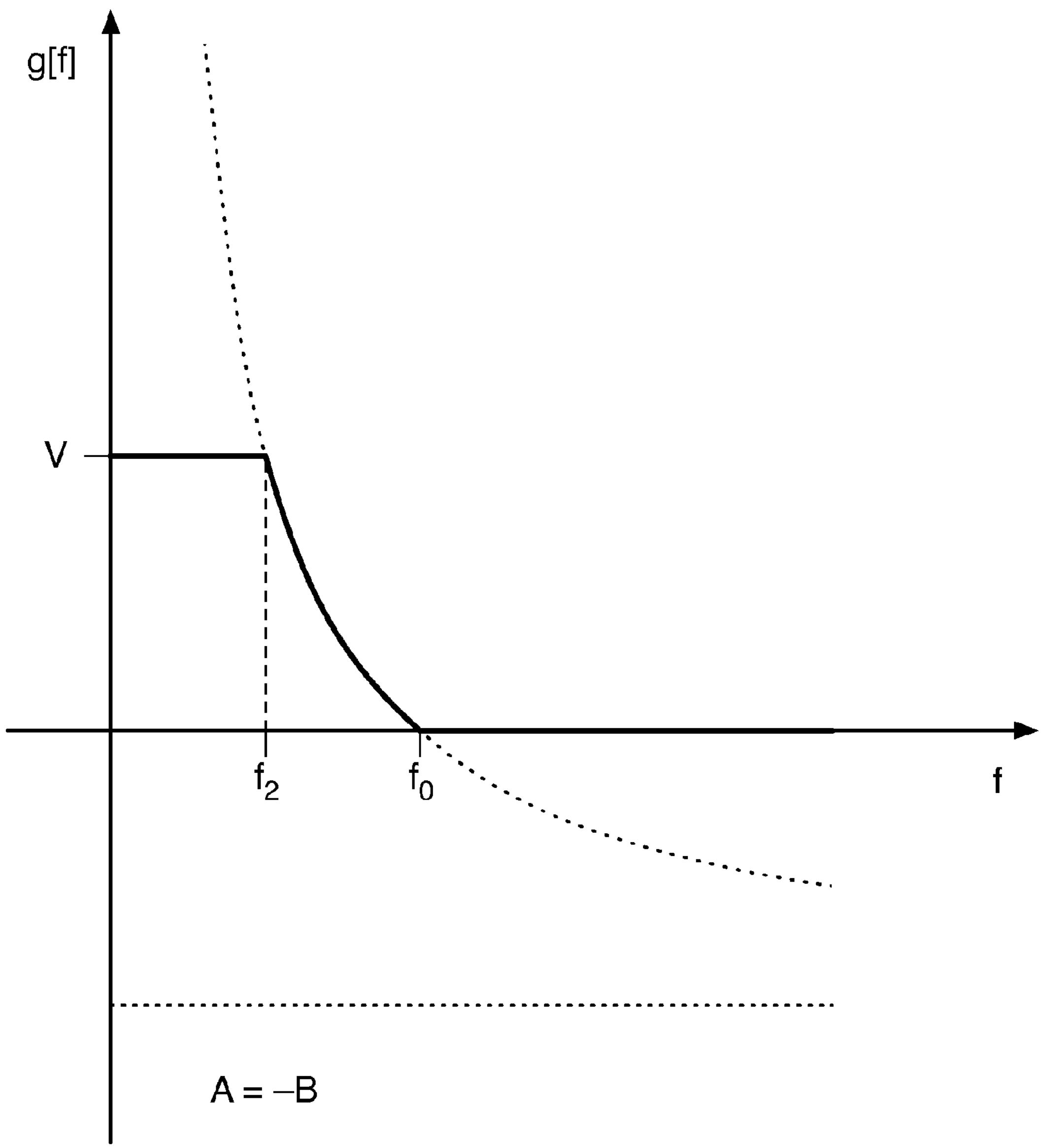


Fig. 2a

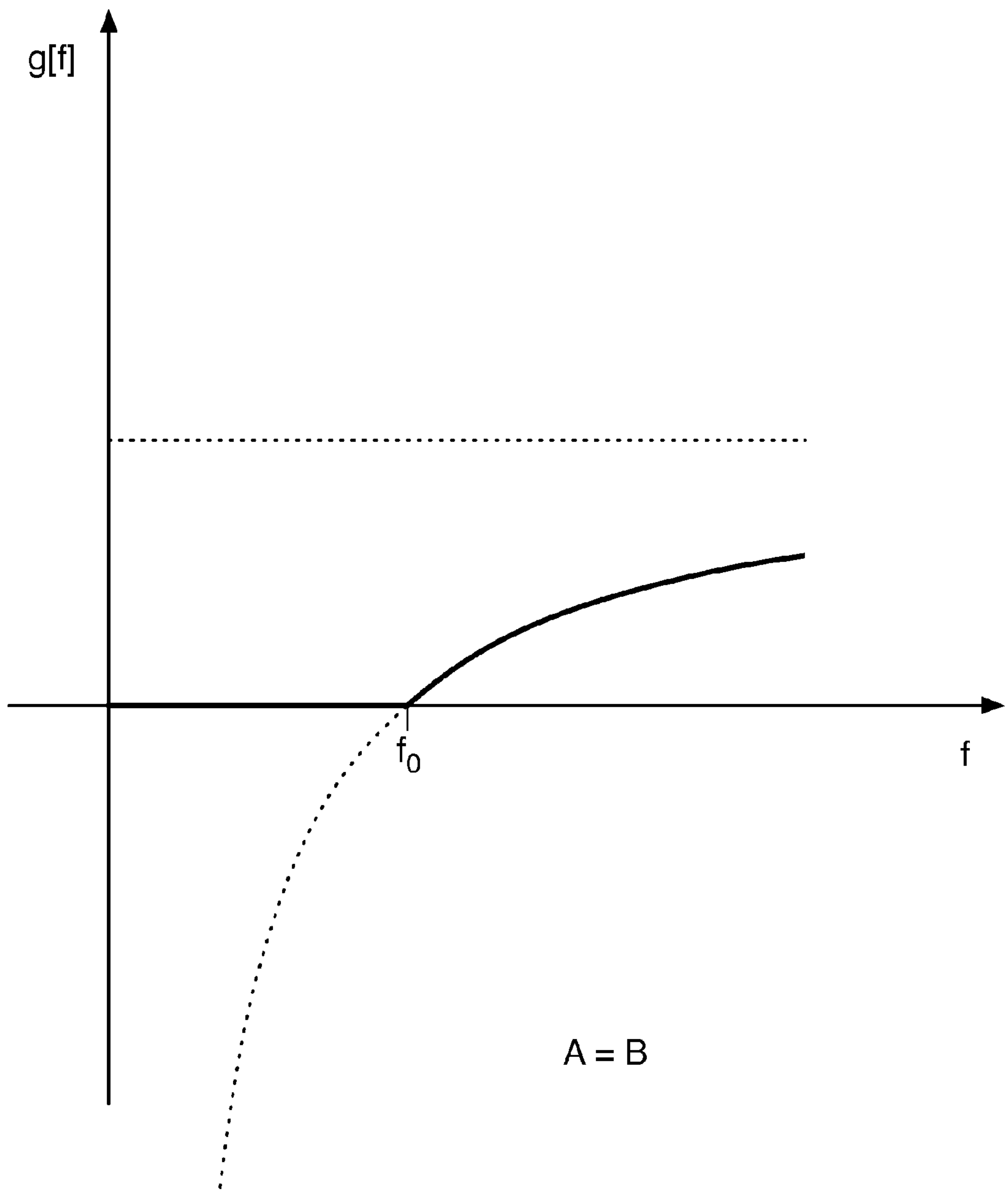


Fig. 2b

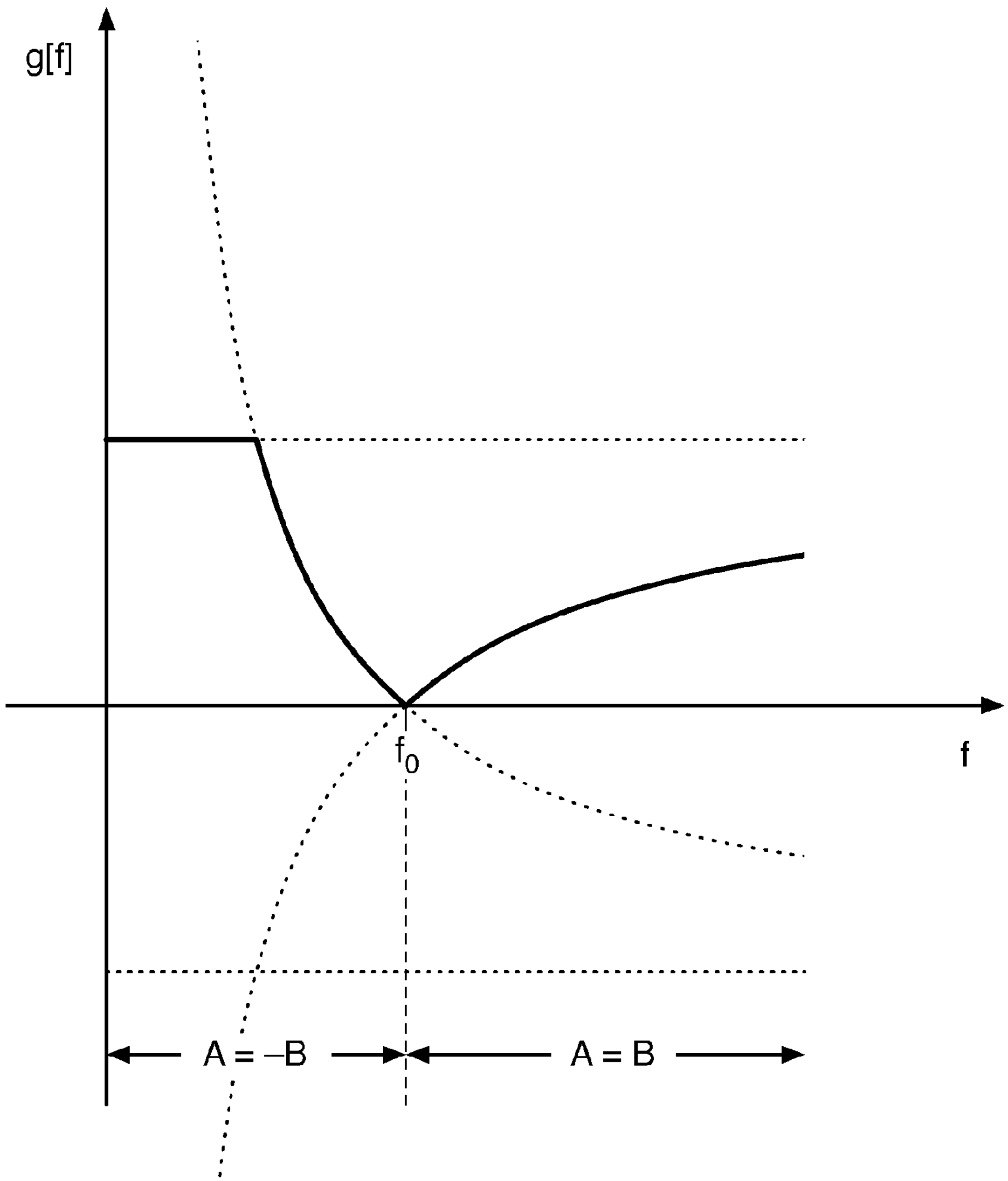


Fig. 2c

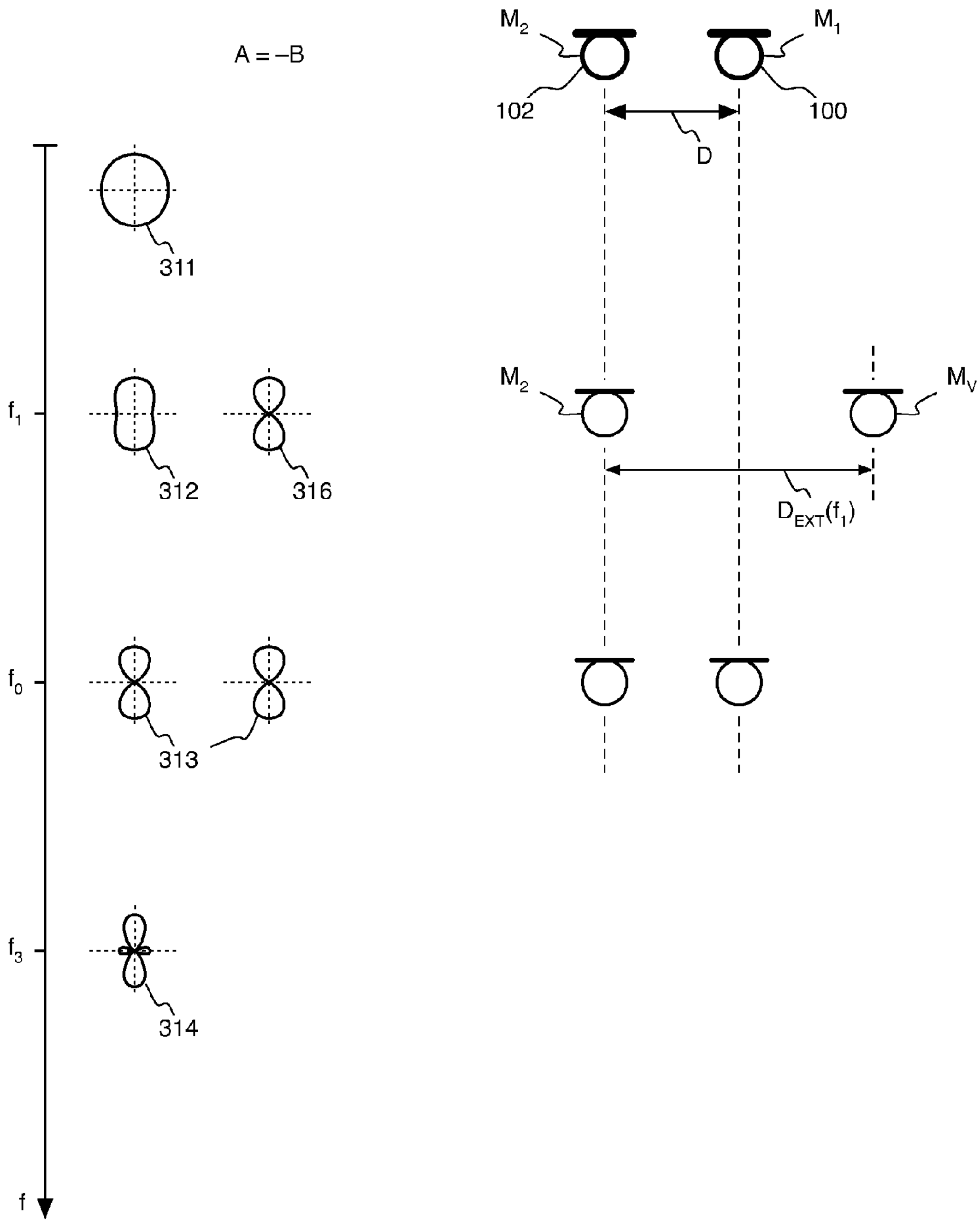


Fig. 3a

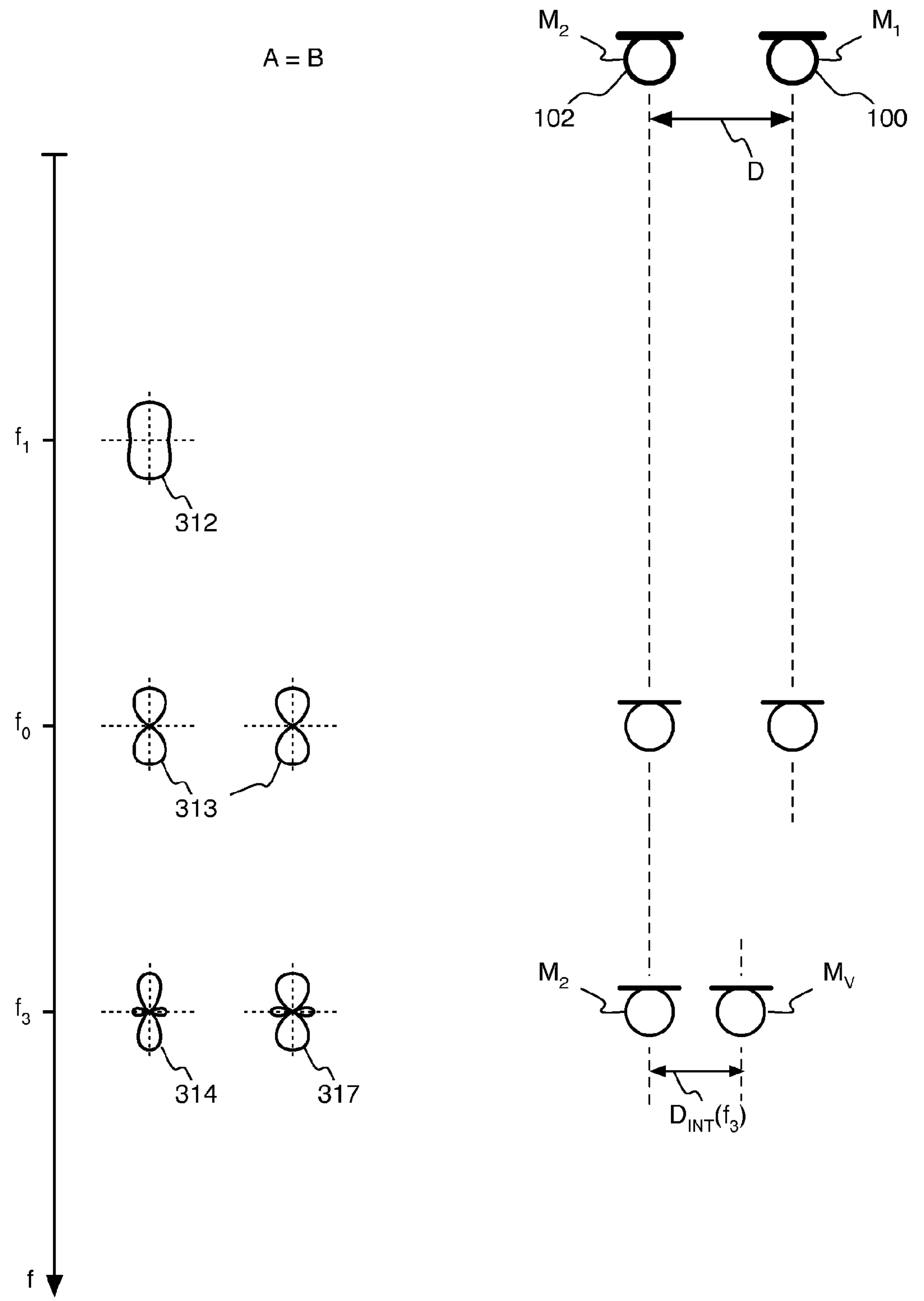


Fig. 3b

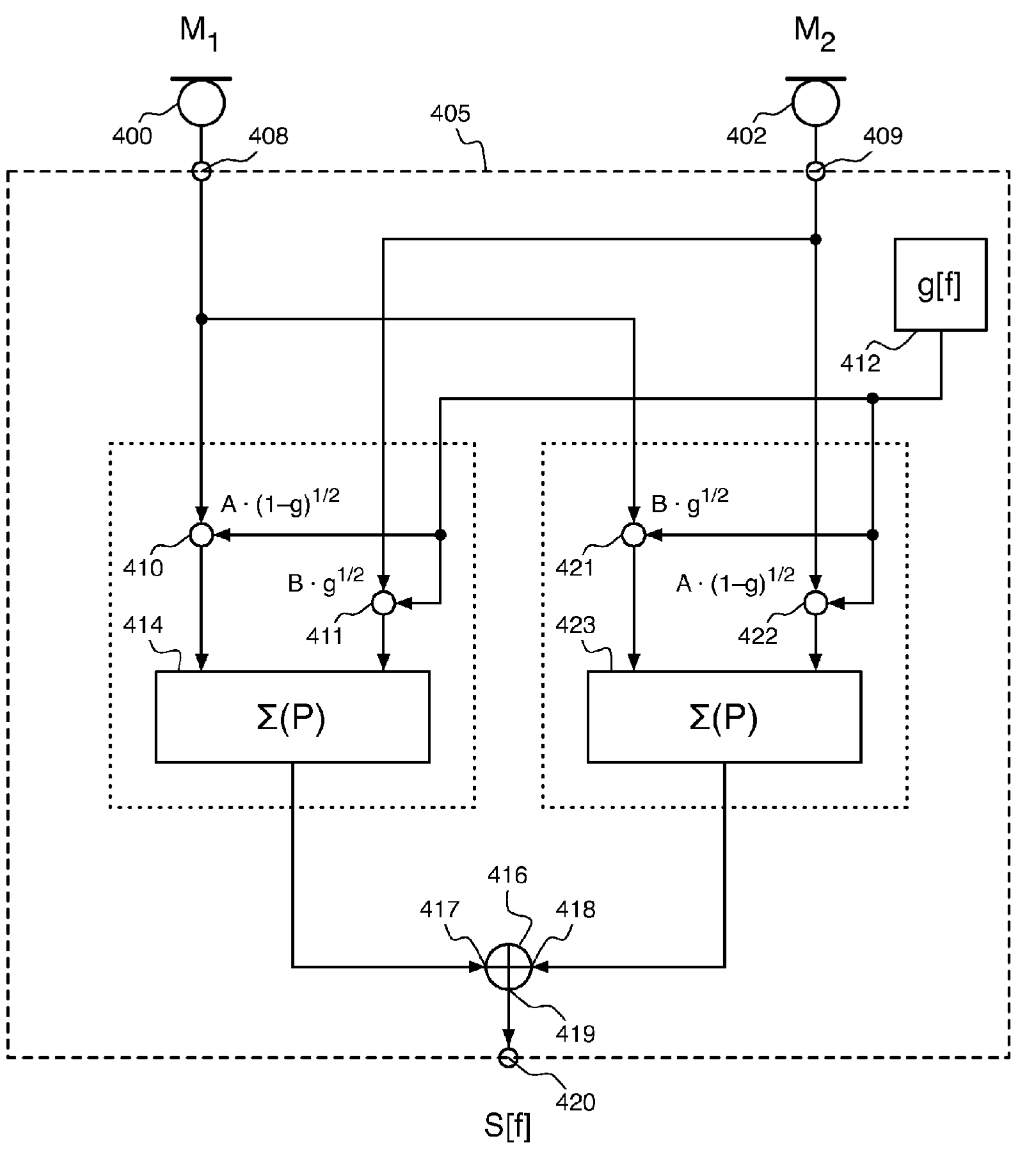

M1
M2
400
408
405
402
409
g[f]
412
A · (1–g)^1/2
B · g^1/2
410
421
B · g^1/2
A · (1–g)^1/2
411
422
414
423
Σ(P)
Σ(P)
416
417
418
419
420
S[f]

Fig. 4

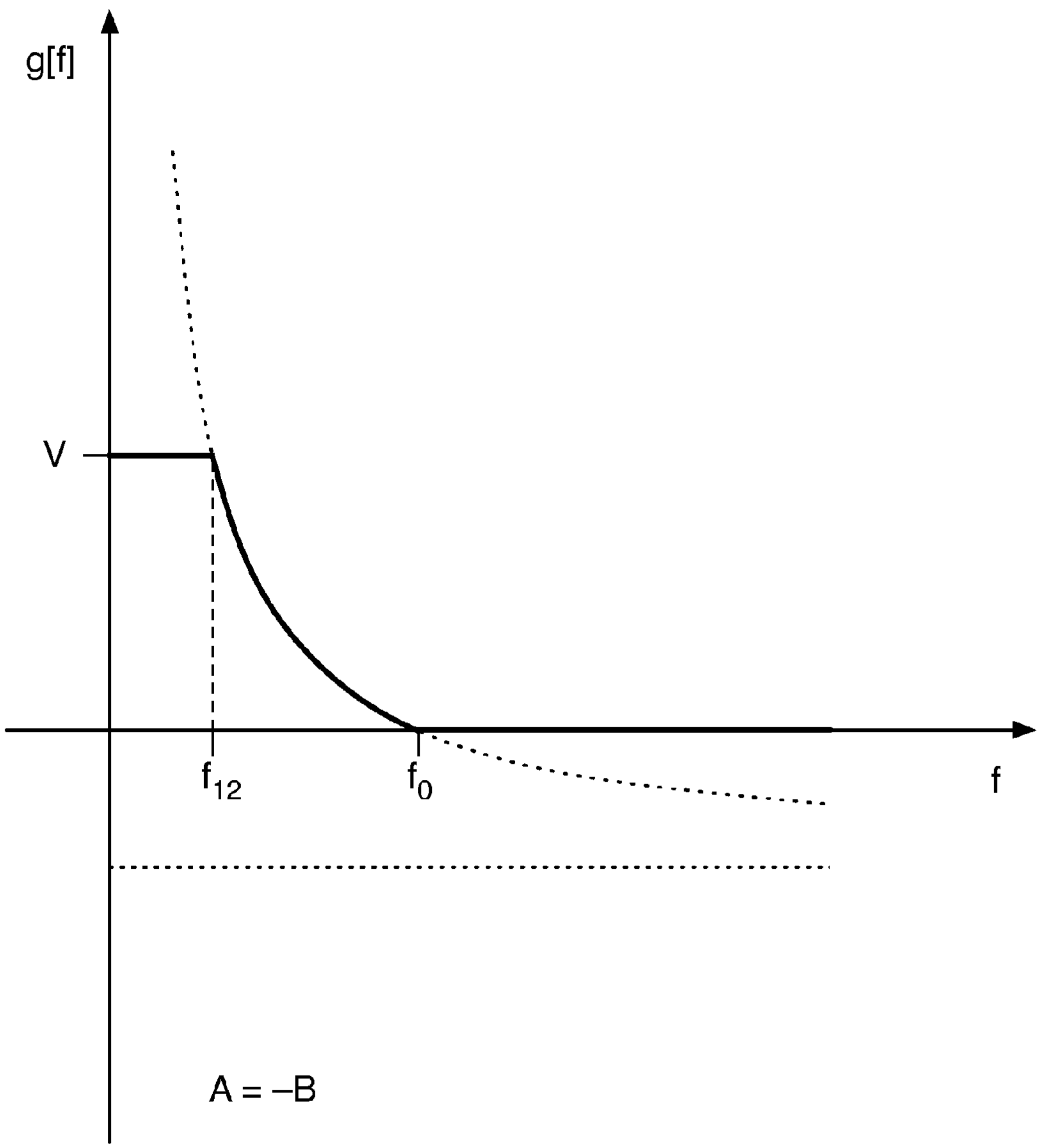


Fig. 5a

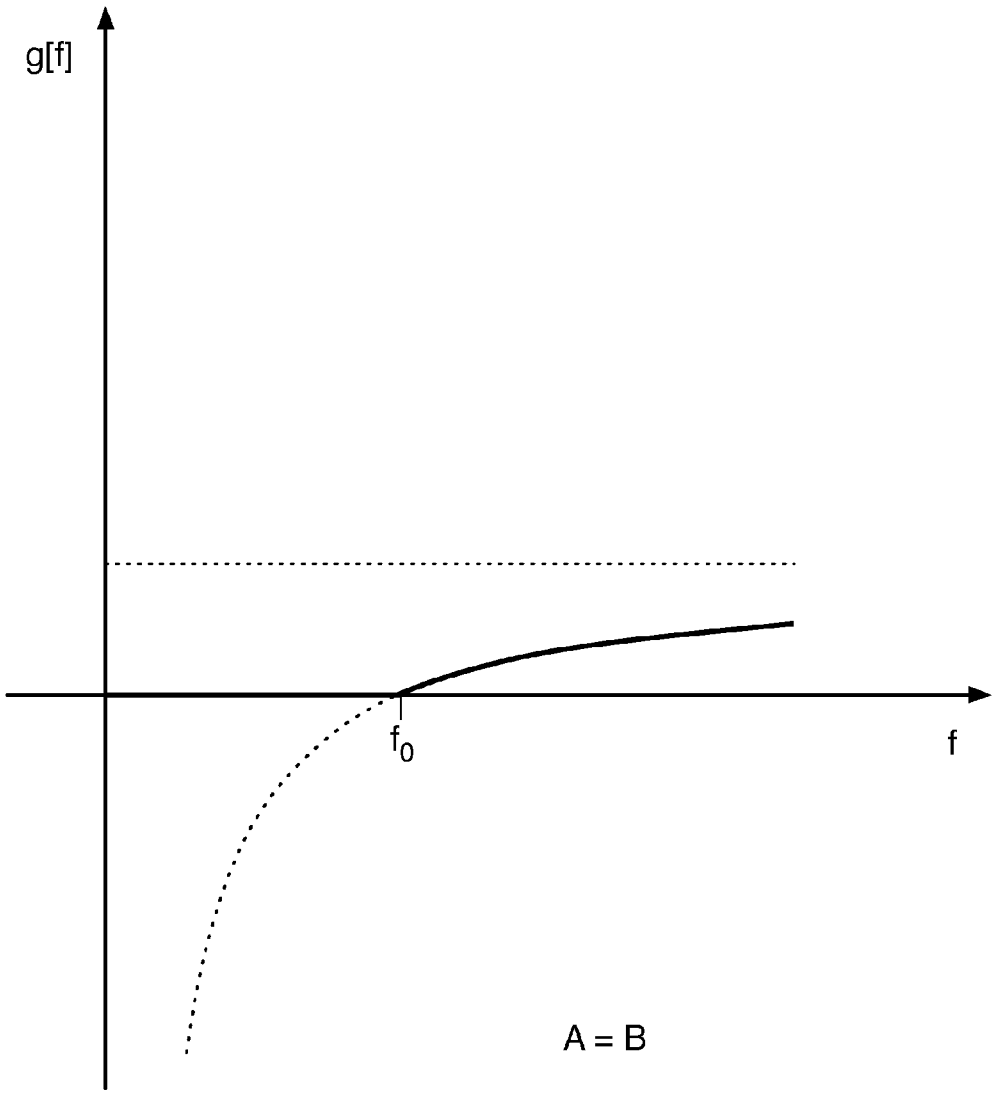


Fig. 5b

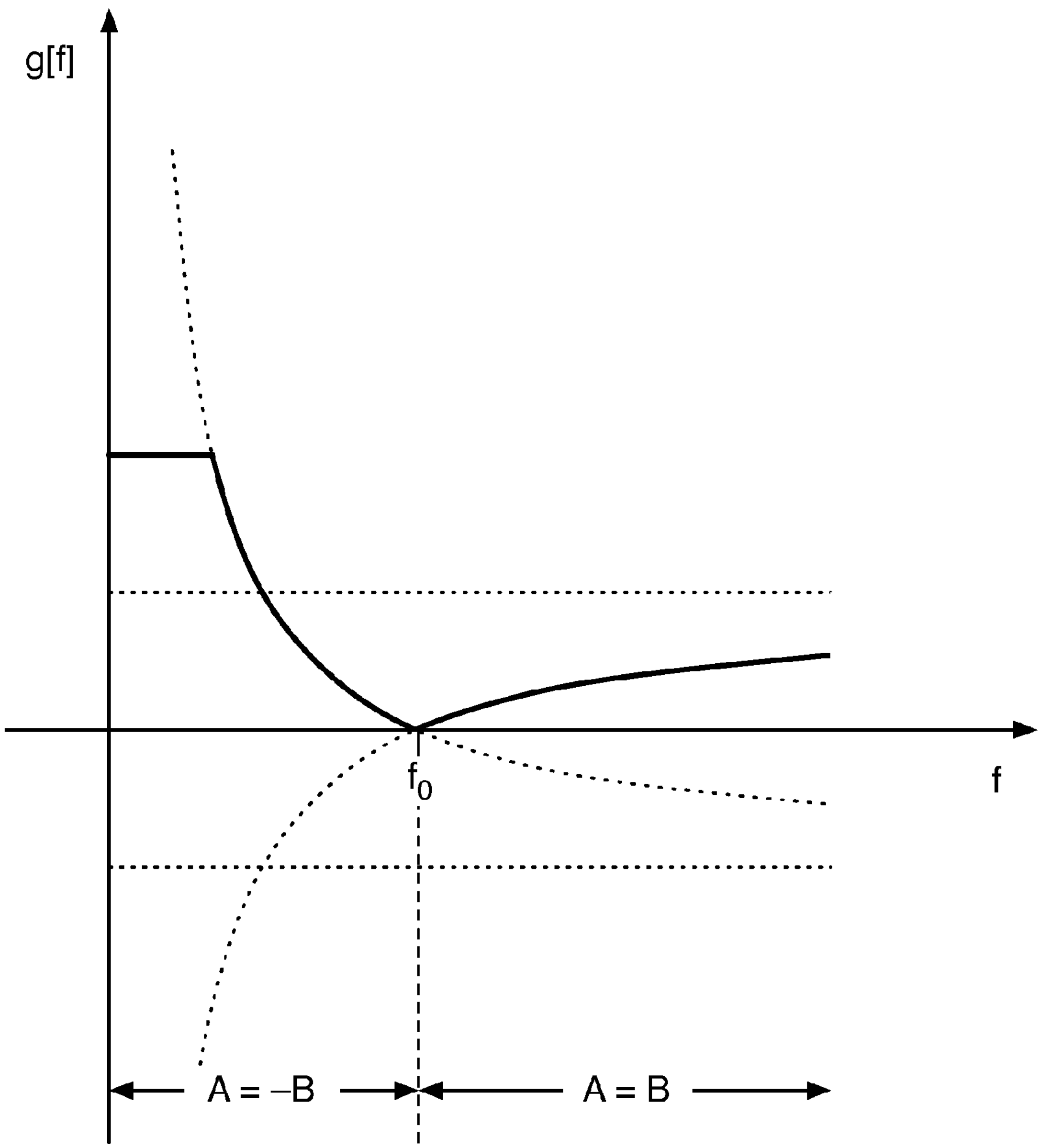


Fig. 5c

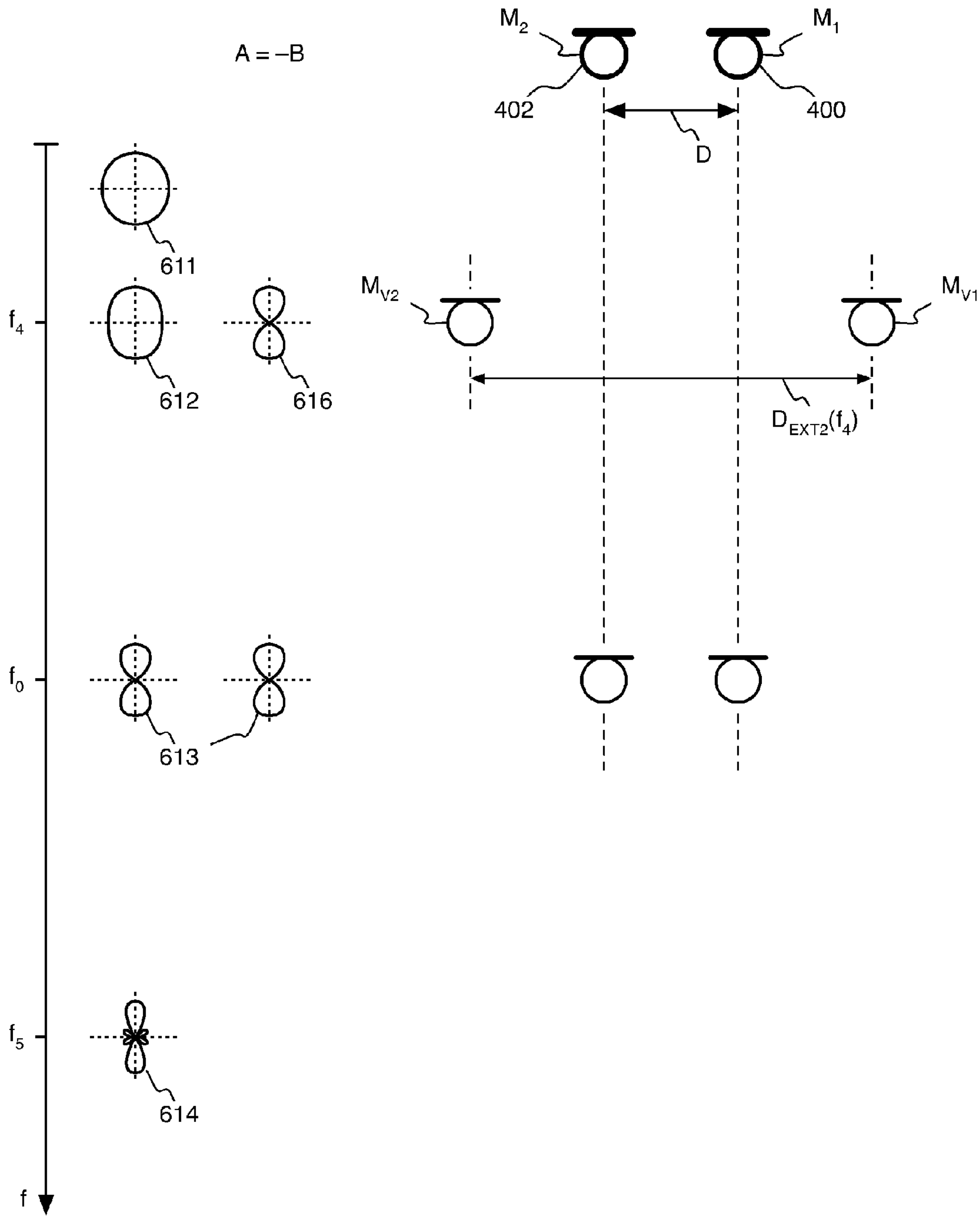


Fig. 6a

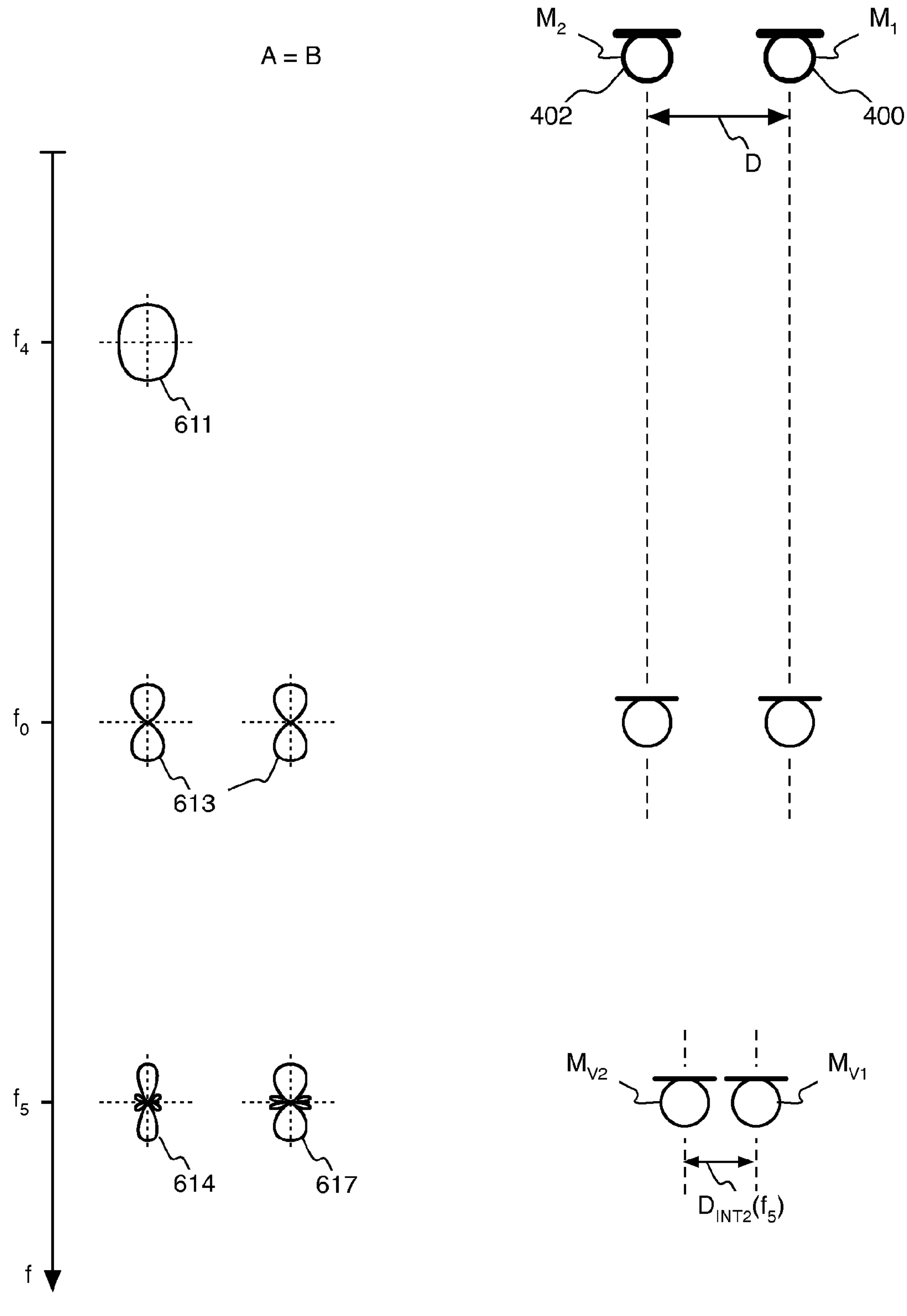
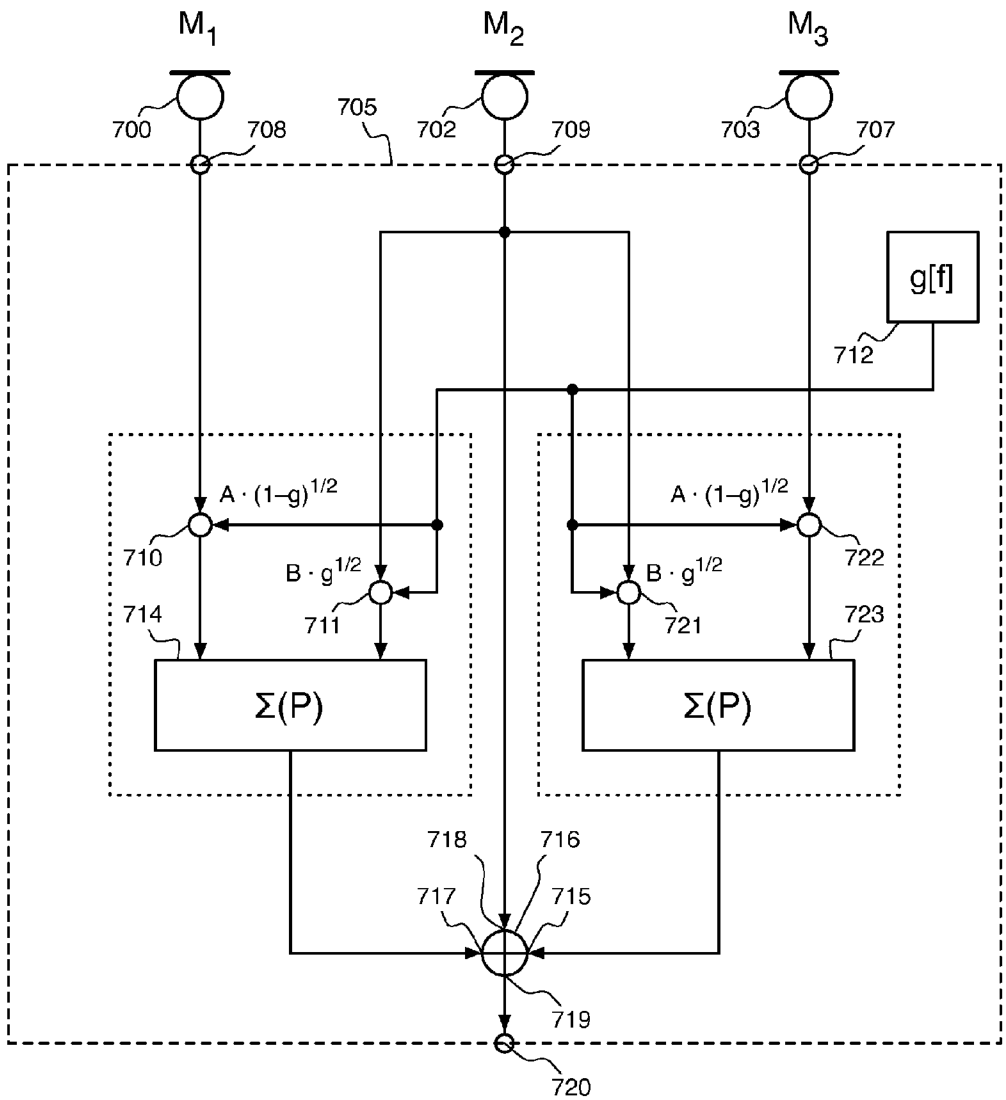


Fig. 6b



M1
M2
M3
700
708
705
702
709
703
707
g[f]
712
A · (1–g)1/2
710
B · g1/2
711
714
Σ(P)
A · (1–g)1/2
722
B · g1/2
721
723
Σ(P)
718
716
717
715
719
720

Fig. 7

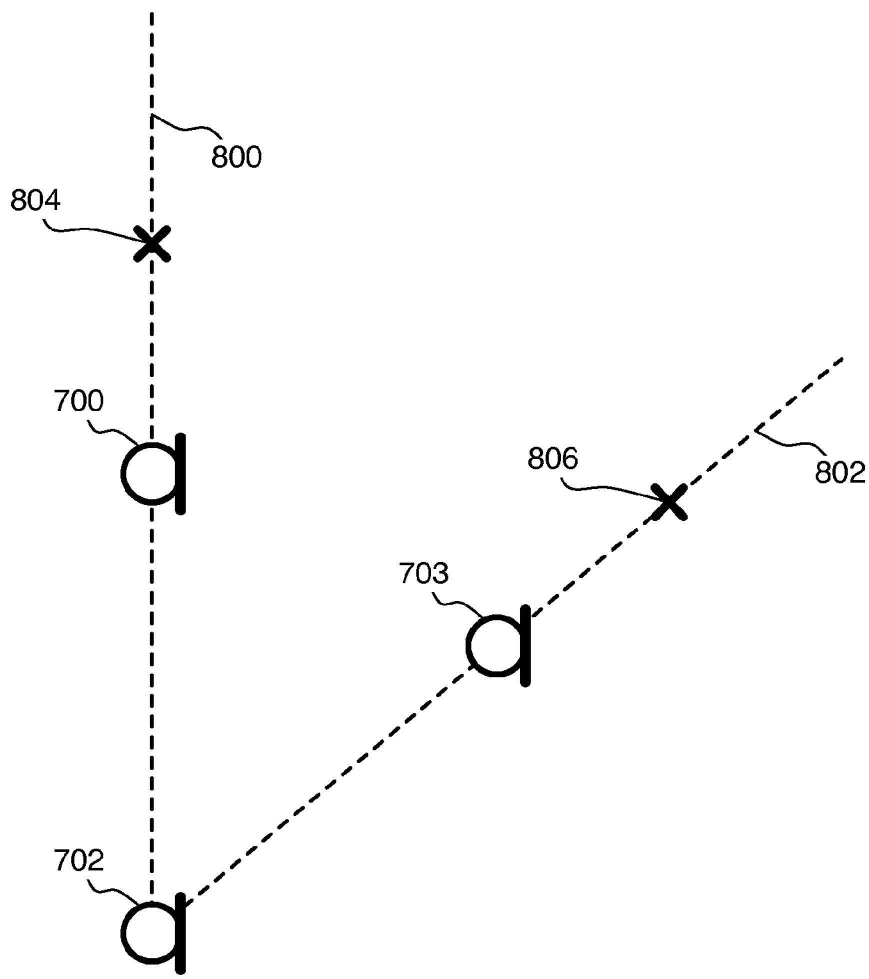


Fig. 8

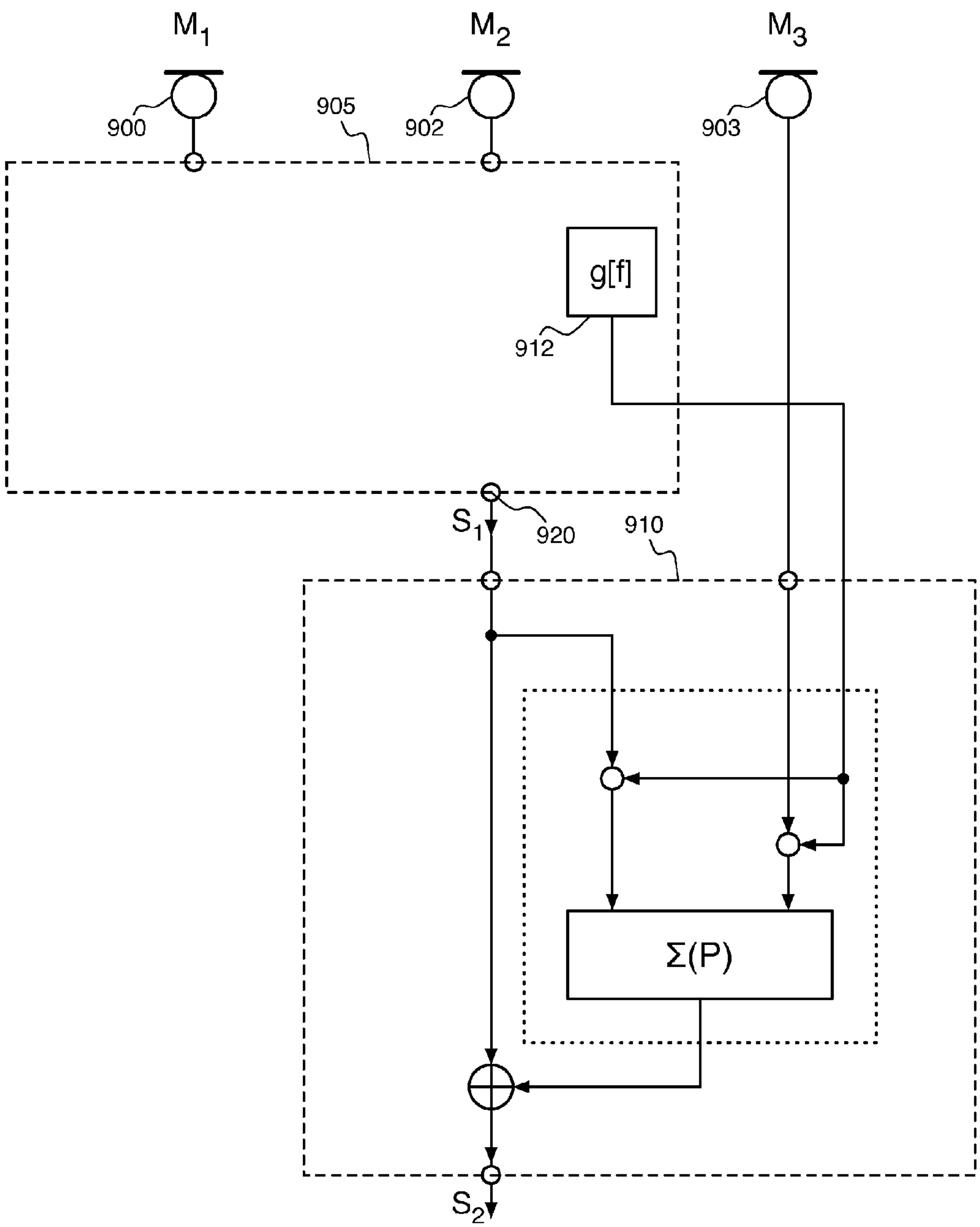


Fig. 9

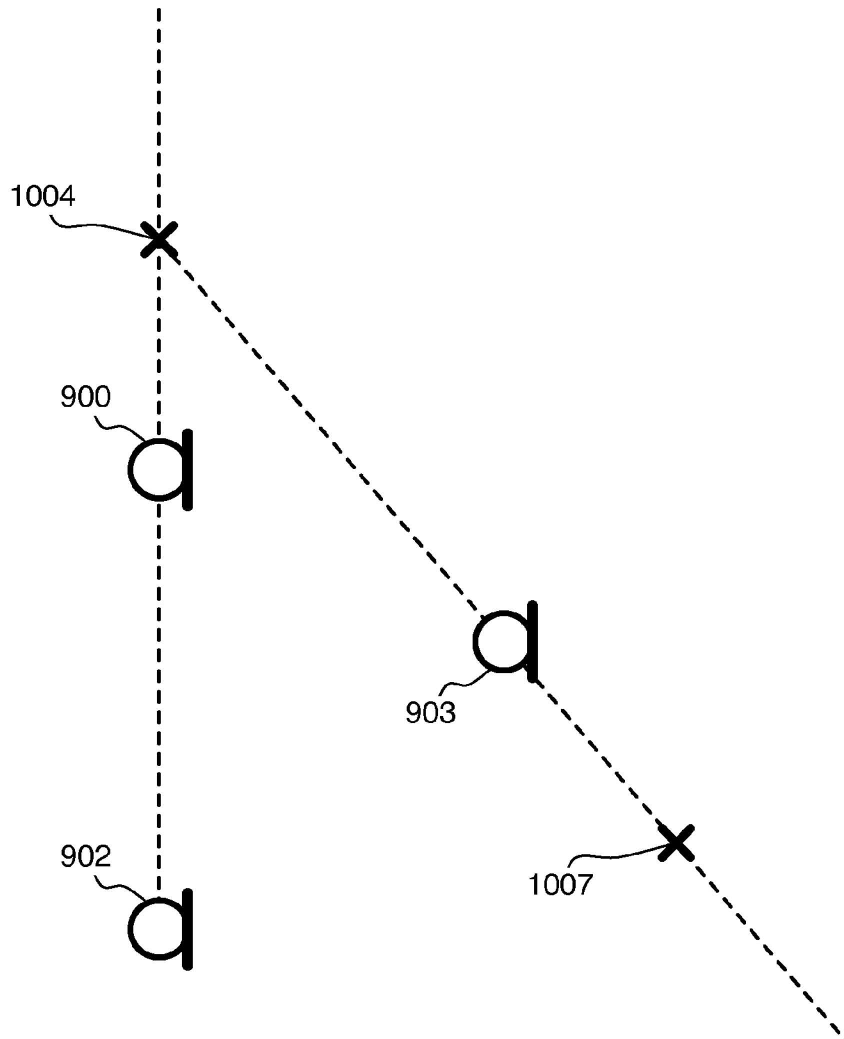


Fig. 10

MICROPHONE ARRANGEMENT WITH IMPROVED DIRECTIONAL CHARACTERISTIC

INTRODUCTION

The invention relates to a microphone arrangement comprising at least two microphones and a signal processing arrangement for deriving a virtual microphone signal from the microphone signals of the at least two microphones. The invention also relates to this signal processing arrangement. A microphone arrangement as defined in the preamble of claim **1**, is known from the published US patent application US2004/0076301. The known microphone arrangement is intended to realise a binaural recording in such a way that a 3D audio playback for a listener is possible.

DESCRIPTION OF THE INVENTION

The present invention, however, is intended to propose a microphone arrangement, the directional characteristic of which can be modified as desired. One target could be, for example, to keep the directional characteristic constant over an increased frequency range.

To this end, the microphone arrangement of the invention is characterised by the features of claim **1**. The signal processing arrangement of the invention is characterised as specified in claim **18**.

The invention is motivated by existing arrangements composed of several microphones, the signals of which are combined (microphone arrays). They are normally intended to increase the directivity relative to one microphone. Directivity means that the sound recorded from a desired direction (main direction) is amplified, whilst the sound recorded from other directions is attenuated. There may be several desired directions if necessary. The directivity of such arrangements is based on the running time of the sound, which causes the direction-dependent phase differences between individual microphone signals. The combination of these signals is normally effected by summation (possibly weighted). But because the phase differences are also frequency-dependent, directivity in consequence becomes frequency-dependent which is a disadvantage, because this results in conventional microphone arrays ending up with only a narrow frequency range in which their directional characteristic is optimal. Outside this frequency range, directivity is worse, which is measurable as a reduced directivity index and which is reflected by the fact that outside the main direction the frequency response is not the same as in the main direction, in particular is not flat.

The invention introduces a technique by which initially virtual microphone signals are generated from the microphone signals and then the virtual microphone signals are mixed. The virtual microphone signals correspond to such signals as if they were coming from imaginary microphones if these were positioned outside the actual microphone positions. The virtual positions are interpolated or extrapolated from the actual microphone positions. In this way an effect is achieved as if the microphone array were becoming smaller (when interpolated) or becoming larger (when extrapolated). The interpolation or extrapolation of positions corresponds to an interpolation or extrapolation of microphone signals and is thus controllable. When generating virtual microphone signals, the interpolation or extrapolation is controlled, according to the invention, as a function of the frequency in order to make the virtual positions frequency-dependent. As a result the frequency dependency of the directivity of the microphone array can also be modified as desired, and the directional characteristic can be optimised across an increased frequency range, for example in such a way that it remains mostly constant.

SHORT DESCRIPTION OF THE FIGURES

The invention will now be described with the reference to the drawing by way of some exemplary embodiments, in which

FIG. **1** shows a first embodiment of a microphone arrangement according to the invention,

FIGS. **2***a*, **2***b* and **2***c* show three curves indicating the behaviour of the multiplication factor g[f] as a function of the frequency f, in the microphone arrangement of FIG. **1**,

FIGS. **3***a* and **3***b* show some directional characteristics of a known microphone arrangement of FIG. **1**,

FIG. **4** shows a second embodiment of a microphone arrangement according to the invention,

FIGS. **5***a*, **5***b* and **5***c* show three curves indicating the behaviour of the multiplication factor g[f] as a function of the frequency f, in the microphone arrangement of FIG. **4**,

FIGS. **6***a* and **6***b* show some directional characteristics of a known microphone arrangement and a microphone arrangement of FIG. **4**,

FIG. **7** shows a third embodiment of a microphone arrangement according to the invention,

FIG. **8** shows the position of the microphones of the microphone arrangement according to FIG. **7**,

FIG. **9** shows a fourth embodiment of a microphone arrangement according to the invention, and

FIG. **10** shows the position of the microphones of the microphone arrangement according to FIG. **9**.

DESCRIPTION OF THE FIGURES

FIG. **1** shows a first embodiment of the microphone arrangement according to the invention. The microphone arrangement is provided with two microphones **100**, **102** and a signal processing arrangement **105** for deriving a virtual microphone signal from the microphone signals of the two microphones **100** and **102**. The signal processing arrangement **105** is provided with a first and a second input **108** and **109** for receiving the microphone signals of the two microphones **100** and **102**, respectively. A first and a second multiplication circuit **110**, **111** is provided with signal inputs coupled with the first and second inputs **108**, **109** of the signal processing arrangement, respectively, with control inputs for receiving respective first and second control signals, respectively, and with signal outputs. The signal processing arrangement **105** further includes a control signal generator **112** for generating the first and second control signals. An arrangement **114** for power-corrected summation is provided, with a first and a second input coupled with the output of the first and second multiplication circuits **110**, **111**, respectively, and with an output. The arrangement **114** is configured for power-corrected summation of the signals offered at its first and second inputs and for providing a power-corrected summed overall signal to the output.

Power-corrected summation arrangements, as understood here, are known from the literature. In this respect reference should be made to the WO2011/057922A1 and the previously filed but not yet published PCT/EP2012/069799 of the same applicant, in particular to the description of FIGS. 2, 6 and 7, which are therefore regarded as being hereby incorporated by reference.

A signal combining arrangement **116** is provided, with a first input **117** coupled with the output of the power-corrected summation arrangement **114**, a second input **118** coupled with one of the at least two microphones, in this case microphone **102**, and with an output **119** coupled with the output **120** of the signal combining arrangement **116**.

The first multiplication circuit **110** is configured for multiplying the signal at its input with a multiplication factor $A\cdot(1-g)^{1/2}$ under the influence of the first control signal of the control signal generator **112**. The second multiplication circuit **111** is configured for multiplying the signal at its input with a multiplication factor $B\cdot g^{1/2}$ under the influence of the second control signal of the control signal generator **112**. According to the invention, g is frequency-dependent and thus indicated as g[f], and A and B are constant values, the absolute values of which are preferably equal 1. Further, A=B or A=−B applies.

FIG. **2***a* shows, what the frequency-dependent behaviour of the multiplication factor g[f] might look like. In this embodiment, A=−B applies.

In FIG. **2***a*, the multiplication factor g[f] between a first frequency value f_0 and a second frequency value f_0 shows an increasingly diminishing value f_2 as the frequency increases. Below the frequency value f_2, g[f] is a constant value V, preferably equal 1. Above the first frequency value f_0, g[f] is constant in turn, preferably equal zero. In the frequency range between f_2 and f_0, g[f] decreases continuously as the frequency increases.

The mode of operation of the microphone arrangement as shown in FIG. **1** with the behaviour for g[f] as shown in FIG. **2***a* will now be explained in detail with reference to FIG. **3***a*. FIG. **3***a* shows the directional characteristics of a microphone arrangement with two microphones as shown in FIG. **1**, which are arranged at a distance D from each other and the output signals of which are directly added together. For low frequencies the directional characteristic is as shown by **311**, i.e., spherical. For increasing frequencies the directional characteristic changes as indicated by the directional characteristics **312**, **313** and **314**. Here the directional characteristic **313** is assumed to be the desired directional characteristic because the directivity of the microphone arrangement is at its highest. Directivity is defined as the ratio of sensitivity in a main direction versus mean sensitivity of the microphone arrangement in all directions. The spherical characteristic **311** is too sensitive for sound from directions outside the main directions, and the same applies to the directional characteristic **314**. The frequency f_0, at which the optimal directional characteristic occurs, depends on the distance D, as follows:

$$f_o = C/(2\cdot D)$$

wherein C is the speed of sound.

It is the object of the invention to maintain this optimal directional characteristic **313** constant for an increased frequency range. This is achieved in the following way: Signal processing in the circuit parts **110**, **111**, and **114** leads to a virtual microphone signal of a virtual microphone Mv at the output of the device **114**, which microphone is situated either between the two microphones **100** and **102** (whereby an interpolation of the microphone signals is performed by the circuit parts **110**, **111** and **114**) or outside the two microphones **100** and **102** (whereby an extrapolation of the microphone signals is performed by the circuit parts **110**, **111** and **114**). In consequence the virtual microphone signal of the virtual microphone (which is present at the output of the arrangement **114**) and the microphone signal of the microphone **102** are combined in the signal combining arrangement **116** for deriving the output signal at the output **120**. The distance between the virtual microphone and the microphone **102** is smaller for an interpolation than the distance between the microphones **100** and **102** and larger for an extrapolation.

An extrapolation in the signal processing arrangement **105** is achieved in case A=−B. For example A could be equal to 1. If we assume this, then this means for the signal processing arrangement **105** that the multiplication factor in the multiplication circuit **111** is equal to $-g^{1/2}$ and the multiplication factor in the multiplication circuit **110** is equal to $(1-g)^{1/2}$. Extrapolation means that the distance D_{EXT} between the virtual microphone Mv and the microphone **102** is larger than D, and thus the frequency at which the optimal directional characteristic occurs is below f_0, e.g., occurs at f_1, as indicated by the directional characteristic **316** in FIG. **3***a*. Because of the frequency dependency of g[f], as indicated in FIG. **2***a*, this means that this optimal directional characteristic is largely maintained in a frequency range between f_0 and f_2 as indicated by the frequency characteristics **313** and **316** in FIG. **3***a*. Since g[f] is constant above f_0, preferably equal to zero, the directional characteristic of the microphone arrangement for frequencies above f_0 remains unchanged.

For $f<f_2$, g cannot increase beyond the value 1 because g=1 is the maximum possible value, for which $(1-g)^{1/2}$ can be calculated.

It should be mentioned that in the above description the correlation between D_{EXT}, depending on the frequency, and g[f] is as follows:

$$D_{EXT}(f)/D \approx 1+g[f] \text{ for } f_2<f<f_0$$

Further,

$$f_0/f \approx D_{EXT}(f)/D$$

applies.

An interpolation in the signal processing arrangement **105** is achieved in case A=B, wherein the multiplication factor g[f] behaves as a function of the frequency, as indicated in FIG. **2***b*. For frequencies below f_0, g[f] is equal to a constant, preferably equal to zero. For frequencies above f_0, the multiplication factor g[f] increases in value as the frequency increases. Preferably, the multiplication factor g[f] continuously increases in value above f_0 as the frequency increases.

The interpolation will now be described with reference to FIG. **3***b*. For simplicity's sake let it be assumed that A=B=1. This means that in the signal processing arrangement **105** in FIG. **1** the multiplication factor in the multiplication circuit **111** is $g^{1/2}$ and the multiplication factor in the multiplication circuit **110** is $(1-g)^{1/2}$. For an interpolation, the distance between the virtual microphone M_v and microphone **102** is smaller than D, and thus the frequency, at which the optimal directional characteristic occurs, is above f_0, e.g., at f_3, as indicated in FIG. **3***b* by the directional characteristic **317**. Due to the frequency dependency of g[f], as indicated in FIG. **2***b*, this means that this optimal directional characteristic is now largely maintained in a frequency range above f_0, as indicated by the frequency characteristics **313** and **317** in FIG. **3***b*.

It should be mentioned that in the above description the correlation between D_{INT}, depending on the frequency, and g[f] is as follows:

$$D_{INT}(f)/D \approx 1-g[f] \text{ for } f \gtrapprox f_0$$

Further,

$$f_0/f \approx D_{INT}(f)/D$$

applies.

Therefore, due to the microphone arrangement according to FIG. **1**, an enlargement of the frequency range for which the optimal directional characteristic is maintained, is possible only towards low frequencies, or only towards higher frequencies, depending upon the values for A and B. In the first case A=−B, and preferably: A=1 and B=−1. In the second case A=B, and preferably A=B=1.

FIG. **2***c* shows a behaviour of the multiplication factor g[f] as a function of f, which for frequencies below f_0 is equal to the behaviour of the multiplication factor in FIG. **2***a*, and for frequencies above f_0 is equal to the behaviour of the multiplication factor in FIG. **2***b*. In this way the extrapolations and interpolations are combined which means that the microphone arrangement in FIG. **1** has a directional characteristic which in a frequency range between f_1 and f_3 has a largely optimal directional characteristic, as indicated by **313**, **316** and **317** in FIGS. **3***a* and **3***b*.

FIG. **4** shows a second exemplary embodiment of the microphone arrangement according to the invention.

The microphone arrangement according to FIG. **4** shows great similarities with the microphone arrangement of FIG. **1**. The circuit parts in the signal processing arrangement **405**, which in FIG. **4** are designated **410**, **411**, **412**, **414**, and **416**, are similar to the circuit parts **110**, **111**, **112**, **114**, **116** of the signal processing arrangement **105** in FIG. **1**. The signal processing arrangement **405** in FIG. **4** is further provided with a third and a fourth multiplication circuit **421**, **422**. The third and fourth multiplication circuits **421** and **422** are provided with signal inputs coupled with the first or the second input **408** or **409** of the signal processing arrangement **405**, with control inputs for receiving respective first or second control signals, and with signal outputs.

An arrangement **423** for power-corrected summation is provided with a first and a second input coupled with the output of the third or fourth multiplication circuit **421**, **422**, and an output. The arrangement **423** is configured for power-corrected summation of the signals offered at its first and second inputs and for providing a power-corrected summed overall signal at the output which is coupled with the second input **418** of the signal combining arrangement **416**.

The third multiplication circuit **421** is configured for multiplying the signal at its input with a multiplication factor $B \cdot g^{1/2}$, under the influence of the second control signal. The fourth multiplication circuit **422** is configured for multiplying the signal at its input with a multiplication factor $A \cdot (1-g)^{1/2}$ under the influence of the first control signal. Both control signals are generated by the control signal generator **412**. Exactly as already mentioned with reference to FIG. **1**, g is frequency-dependent according to the invention and A and B are constant values, the absolute values of which are preferably equal 1. Further, A=B or A=−B applies.

The arrangement **423** is preferably identical with the arrangement **414**.

FIG. **5***a* shows what the frequency-dependent behaviour of the multiplication factor g[f] could look like. In this case A=−B.

The multiplication factor g[f] in FIG. **5***a* shows a frequency value which decreases for an increasing frequency between a first frequency value f_0 and a second frequency value f_{12}. Below the frequency value f_{12}, g[f] is a constant value V, preferably equal 1. Above the first frequency value f_0, g[f] is again constant, preferably equal zero. In the frequency range between f_{12} and f_0, g[f] continuously decreases as the frequency increases.

The mode of operation of the microphone arrangement of FIG. **4** with a behaviour for g[f] as shown in FIG. **5***a* will now be explained in detail with reference to FIG. **6***a*. FIG. **6***a* shows the directional characteristics of a microphone arrangement with two microphones, as shown in FIG. **4**, which are arranged at a distance D from each other and the output signals of which are directly added together.

For low frequencies, the directional characteristic as indicated with **611**, is again spherical. For increasing frequencies, the directional characteristic changes as has already been described with reference to FIG. **3***a* and as indicated by the directional characteristics **612**, **613** and **614**. The directional characteristic **613** is again assumed as being the desired directional characteristic, for the same reasons as already explained in conjunction with FIG. **3***a*. The frequency f_0, at which the optimal directional characteristic occurs, is given by

$$f_0 = C/(2 \cdot D)$$

wherein C is the speed of sound.

It is the object of the invention to keep the optimal directional characteristic **613** largely constant for an increased frequency range. This is achieved as follows. Signal processing in the circuit parts **410**, **411** and **414** leads, as already explained with reference to FIGS. **3***a* and **3***b*, to a virtual microphone signal of a virtual microphone at the output of the arrangement **414**, which microphone is situated either between the two microphones **408** and **409** (whereby an interpolation of the microphone signals is performed by the circuit parts **410**, **411** and **414**) or which is situated outside the two microphones **408** and **409** (whereby an extrapolation of the microphone signals is performed by the circuits parts **410**, **411** and **414**).

Exactly the same applies, of course, to the signal processing in the circuit parts **421**, **422** and **423**. This means that a microphone signal of a virtual microphone is also generated at the output of the arrangement **423**.

An extrapolation in the microphone arrangement of FIG. **4** is achieved for the case A=−B. A, for example, could be equal to 1. At the output of the arrangement **414** a microphone signal of a virtual microphone M_{v1} is then present, and at the output of the arrangement **423** the microphone signal of a virtual microphone M_{v2} is then present. The positions of both virtual microphones are shown in FIG. **6***a*. Extrapolation in this case means that the distance D_{EXT2} between the two virtual microphones M_{V1} and M_{V2} is not only larger than D but also larger than D_{EXT} in FIG. **3***a*.

Thus, the frequency range at which the desired directional characteristic is largely maintained, may be enlarged towards even lower frequencies, i.e., in a frequency range between f_0 and f_{12}, in FIG. **6***a*. Since g[f] is constant above f_0, preferably equal to zero, the directional characteristic of the microphone arrangement for frequencies above f_0 remains unchanged.

For $f<f_{12}$, g cannot increase beyond the value 1 for decreasing frequencies because g=1 is the maximum possible value for which $(1-g)^{1/2}$ can be calculated.

It should be mentioned that in the above description the correlation between D_{EXT}, dependent on the frequency, and g[f] is as follows:

$$D_{EXT}(f)/D \approx \tfrac{1}{2} + g[f] \text{ for } f_{12} < f < f_0$$

Further,

$$f_0/f \approx D_{EXT}(f)/D$$

applies.

An interpolation in the microphone arrangement of FIG. **4** is achieved for the case A=B, wherein the multiplication factor g[f] behaves as a function of the frequency as indicated in FIG. **5***b*. For frequencies below f_0, g[f] is equal to a constant, preferably equal zero. For frequencies above f_0 the multiplication factor g[f] increases in value as the frequency increases. Preferably the multiplication factor g[f] above f_0 continuously increases in value as the frequency increases.

The interpolation will now be described with reference to FIG. **6**b. For simplicity's sake it is assumed that A=B=1.

The microphone signal of a virtual microphone M_{v1} is then present at the output of the arrangement **414**, and the microphone signal of a virtual microphone M_{v2} is then present at the output of the arrangement **423**. The positions of both virtual microphones are shown in FIG. **6**b. The interpolation means in this case that the distance D_{INT2} between the two virtual microphones M_{v1} and M_{v2} is not only smaller than D, but also smaller than D_{INT} in FIG. **3**b.

Thus the frequency range, at which the desired directional characteristic is largely maintained, can be enlarged towards higher frequencies, i.e., in the frequency range above f_0 in FIG. **6**b. Since g[f] remains constant, preferably equaling zero for frequencies below f_0, the directional characteristic of the microphone arrangement for frequencies below f_0 remains unchanged.

It should be mentioned that in the above description the correlation between D_{INT}, dependent on the frequency, and g[f] is as follows:

$$D_{INT}(f)/D \approx 1/2 - g[f] \text{ for } f \gtrapprox f_0$$

Further,

$$f_0/f \approx D_{INT}(f)/D$$

applies.

FIG. **6**c shows a behaviour of the multiplication factor g[f] as a function of f, which for frequencies below f_{10} is equal to the behaviour of the multiplication factor in FIG. **6**a and for frequencies above f_{10} is equal to the behaviour of the multiplication factor in FIG. **6**b. In this way, the extrapolation and the interpolation are combined, which means that the microphone arrangement in FIG. **4** has a directional characteristic which in a frequency range between f_4 (see FIG. **6**a) and f_5 (see FIG. **6**b) has a largely optimal directional characteristic, as indicated by **613**, **616** and **617** in FIGS. **6**a and **6**b.

Additionally, it should be mentioned that the rising and falling parts of the progression of the multiplication factor g[f] as a function of the frequency as shown in FIGS. **2**a, **2**b, **2**c, **5**a, **5**b and **5**c, behave like parts of a hyperbolic curve. This follows from the inverse proportionality to the frequency in the above-mentioned formulae.

FIG. **7** shows a third exemplary embodiment of the microphone arrangement according to the invention. In this case the microphone arrangement comprises three microphones **700**, **702** and **703**. The signal processing arrangement **705** is now constructed as follows: The circuit parts in the signal processing arrangement **705** indicated in FIG. **7** by **710**, **711**, **712**, **714**, and **716**, are similar to the circuit parts **110** and **111** and **112** and **114** and **116** of the signal processing arrangement **105** in FIG. **1**, respectively. The third microphone **403** is coupled with a third input **707** of the signal processing arrangement **705**. The signal processing arrangement **705** is further provided with a third and a fourth multiplication circuit **721** and **722**. The signal inputs of the multiplication circuits **721** and **722** are coupled with the second input **709** and the third input **707** of the signal processing arrangement **705**, respectively. Control inputs of the multiplication circuits **721** and **722** are coupled with the control signal generator **712** for receiving respective first and second control signals, respectively. Signal outputs of the two multiplication circuits **721** and **722** are coupled with associated inputs of an arrangement **723** for power-corrected summation. One output of the arrangement **723** is coupled with a third input **715** of the signal combining arrangement **716**. The arrangement **723** is configured for power-corrected summation of the signals offered at its first and second inputs and for providing a power-corrected summed overall signal at the output. The third multiplication circuit **721** is configured for multiplying the signal at its input with a multiplication factor $B \times g^{1/2}$ under the influence of the second control signal. The fourth multiplication circuit **722** is configured for multiplying the signal at its input with a multiplication factor $A \times (1-g)^{1/2}$ under the influence of the first control signal.

Both control signals are generated by the control signal generator **712**. Just as already indicated with reference to FIG. **1** according the invention the multiplication factor g is frequency-dependent, and A and B are constant values the absolute values of which are preferably equal 1. Further: A=B or A=−B. The frequency-dependent behaviour of the multiplication factor g[f] in the embodiment of FIG. **7** is again as already described with reference to FIGS. **2**a to **2**c.

The arrangement **723** is preferably identical with the arrangement **714**.

The three microphones **700**, **702** and **703** need not necessarily lie on a straight line. FIG. **8** shows the position of the three microphones **700**, **702** and **703**, which in this case are positioned on intersecting lines. In the embodiment of FIG. **7** two virtual microphone signals are again generated. The first virtual microphone signal is present at the input **717** of the signal combining arrangement **716** and is derived from the microphone signals of the microphones **700** and **702**. The second virtual microphone signal is present at the input **715** of the signal combining arrangement **716** and is derived from the microphone signals of microphones **702** and **703**.

Let it be assumed that in the microphone arrangement of FIG. **7** an extrapolation is performed for obtaining the two virtual microphone signals. This has the effect as if two virtual microphones had been realised. Specifically speaking, as if the microphone **700** were no longer at the position indicated in FIG. **8**, but further away from the microphone **702** on the connection line **800** through the two microphones **700** and **702**, e.g., at the position **804**. Similarly it seems as if the microphone **703** is not at the indicated position, but further away from the microphone **702** on the connection line **802** through the two microphones **702** and **703**, e.g., at the position **806**. The position of the microphone **702** does not change. Due to this other position for the two virtual microphone signals another directional characteristic of the microphone arrangement, of course, is created which can now be modified as desired.

Yet another embodiment of a microphone arrangement with three microphones is shown in FIG. **9**. The microphone signals of two microphones **900** and **902** are processed in the circuit part **905** which can be constructed as shown in FIG. **1** or **4**, in order to obtain an output signal S_1 at the output **920**. The output signal S_1 and the microphone signal of the microphone **903** are then brought together in a circuit part **910** in order to obtain the output signal S_2 of the microphone arrangement. The circuit part **910** may again look like the circuit part **105** shown in FIG. **1** (and as can indeed be seen in FIG. **9**) or like the circuit part **405** shown in FIG. **4**.

The positions of the virtual microphones arise as shown in FIG. **10**. In this case, a first extrapolation is now performed on the microphone signals of the microphones **900** and **902**, whereby a virtual microphone signal S_1 of a first virtual microphone at the position **1004** is derived at the output **920** in FIG. **9**. Thereafter a second extrapolation is performed on the microphone signals of the first virtual microphone at the position **1004** and the microphone **903**, which leads to a second virtual microphone signal of a virtual microphone at the position **1007**, whereby the second virtual microphone signal is present on the line **930** in FIG. **9**. The output signal S_2 at the output of the microphone arrangement is therefore the combination of the two first and second virtual microphone signals.

In conclusion, it should be mentioned that the invention is not limited to the exemplary embodiments shown in the description of the figures. As such various modifications are possible which however, all fall within the scope of the invention. As such the microphone arrangement may be comprised of more than three microphones. The microphones need not necessarily lie on a straight line.

The invention claimed is:

1. A microphone arrangement provided with at least two microphones and a signal processing arrangement for deriving a virtual microphone signal from the microphone signals of the at least two microphones, wherein the signal processing arrangement is provided with

a first and a second input for receiving the microphone signals of the at least two microphones,

a first and a second multiplication circuit, with signal inputs coupled with the first and second input of the signal processing arrangement, respectively, with control inputs for receiving respective first and second control signals, respectively, and with signal outputs,

a control signal generator for generating the first and second control signals,

an arrangement for power-corrected summation, with a first and a second input coupled with the output of the first and second multiplication circuit, respectively, and an output, wherein the arrangement is configured for power-corrected summation of the signals offered at its first and second inputs and for providing a power-corrected summed overall signal at the output,

a signal combining arrangement, with a first input coupled with the output of the power-corrected summation arrangement, a second input coupled with one of the at least two microphones and an output coupled with the output of the signal processing arrangement,

wherein the first multiplication circuit is configured for multiplying the signals at its input with a multiplication factor $A\cdot(1-g)^{1/2}$ under the influence of the first control signal, the second multiplication circuit is configured for multiplying the signal at its input with a multiplication factor $B\cdot g^{1/2}$ under the influence of the second control signal, wherein g is frequency-dependent (g[f]), in that A and B are constant values, the absolute values of which preferably being equal 1, and further A=B or A=−B applies.

2. The microphone arrangement according to claim **1**, wherein the multiplication factor g[f], below a first frequency value, has a smaller value as the frequency increases.

3. The microphone arrangement according to claim **2**, wherein the multiplication factor g[f], below the first frequency value, continuously decreases in value as the frequency increases.

4. The microphone arrangement according to claim **2**, wherein the multiplication factor g[k], below a second frequency value that is smaller than the first frequency value, has a constant value (V).

5. The microphone arrangement according to claim **4**, wherein the constant value (V) is equal to 1.

6. The microphone arrangement according to claim **2**, wherein the multiplication factor g[k], above the first frequency value, has a constant value equal to zero.

7. The microphone arrangement according to claim **1**, wherein A=−B.

8. The microphone arrangement according to claim **1**, wherein the multiplication factor g[k], above the first frequency value, has a larger value as the frequency increases.

9. The microphone arrangement according to claim **8**, wherein the multiplication factor g[k], above the first frequency value, continuously increases in value as the frequency increases.

10. The microphone arrangement according to claim **8**, wherein the multiplication factor g[k], below the first frequency value, has a constant value equal to zero.

11. The microphone arrangement according to claim **8**, wherein A=B.

12. The microphone arrangement according to claim **2**, wherein A=−B for frequency values below the first frequency value, and A=B for frequency values above the first frequency value.

13. The microphone arrangement according to claim **2**, wherein the rising or falling parts of the progression of the multiplication factor g[f] as a function of the frequency show a hyperbolic curve behaviour.

14. The microphone arrangement according to claim **1**, wherein the signal processing arrangement is further provided with

a third and a fourth multiplication circuit, with signal inputs, coupled with the first and second input of the signal processing arrangement, respectively, with control inputs for receiving respective first and second control signals, respectively, and with signal outputs,

an arrangement for power-corrected summation, with a first and a second input coupled with the output of the third and fourth multiplication circuit, respectively, and with an output, wherein the arrangement is configured for power-corrected summation of the signals offered at its first and second inputs and for providing a power-corrected summed overall signal at the output, wherein the output is coupled with the second input of the signal combining arrangement.

15. The microphone arrangement according to claim **14**, wherein the third multiplication circuit is configured for multiplying the signal at its input with a multiplication factor $B\cdot g^{1/2}$ under the influence of the second control signal, and the fourth multiplication circuit is configured for multiplying the signal at its input with a multiplication factor $A\cdot(1-g)^{1/2}$ under the influence of the first control signal.

16. The microphone arrangement according to claim **1**, provided with three microphones, wherein the third microphone is coupled with a third input of the signal processing arrangement, the signal processing arrangement being further provided with

a third and a fourth multiplication circuit, with signal inputs coupled with the second and third input of the signal processing arrangement, respectively, with control inputs for receiving respective first and second control signals, and with signal outputs,

an arrangement for power-corrected summation, with a first and a second input coupled with the output of the third and fourth multiplication circuit, respectively, and an output, wherein the arrangement is configured for power-corrected summation of the signals offered at its first and second inputs and for providing a power-corrected summed overall signal at the output, wherein the output is coupled with a third input of the signal combining arrangement.

17. The microphone arrangement according to claim **16**, wherein the third multiplication circuit is configured for multiplying the signal at its input with a multiplication factor $B\times g^{1/2}$ under the influence of the second control signal, and the fourth multiplication circuit is configured for multiplying the signal at its input with a multiplication factor $A\times(1-g)^{1/2}$ under the influence of the first control signal.

18. A signal processing arrangement for deriving a combination signal (S[f]) from the microphone signals of at least two microphones characterised by wherein the part features of the signal processing arrangement as defined in claim **1**.

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